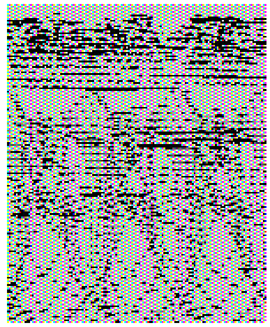

The Utility of Targeting the Petroleum-Based Sector of a Nation's Economic Infrastructure

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Abstract

Modern conventional warfare requires not only adequate military forces, but advanced economic infrastructures capable of supporting these forces. Such infrastructures provide large vulnerable targets susceptible to enemy air attack. Although some targets have little value, this is not the case with oil. The petroleum-based sector of any nation's economy is a vital target, particularly during large, fast-paced conventional operations. This study focuses on the fundamental utility of targeting and attacking generic petroleum systems. When finished, the reader should be able to determine whether targeting oil systems might be useful, and if so, what part of the system to attack.

When considering an oil system as a potential target, one most certainly thinks of World War II, or possibly Vietnam. While these particular conflicts are by no means the only example of targeting oil systems, they provide valuable insights when analyzed. Take, for instance, the case of the Second World War. Prior to the conflict, little thought had been given as to how one might actually go about destroying the petroleum-based sector of a nation's economic infrastructure. As the war progressed, the need for strategic intelligence and civilian expertise soon became evident. Air planners further realized that doctrine did not equal targeting and that centers of gravity were not always within reach. In other words, little thought had been given as to how unescorted, daylight strategic bombing might be used to defeat Germany, to include gaining air superiority by targeting oil systems. Finally, the historical studies of World War II highlight one last lesson, the need to consider collateral effects when targeting oil.

While the success of Allied air attacks during World War II indicates the utility of targeting oil systems during war, the US experience in Vietnam seems to indicate the opposite. Not only did American planners fail to consider the lessons of World War II, but they also employed air power in an inappropriate way—they attacked oil systems without considering the enemy requirements. Not only did the enemy not require large amounts of oil, but neighboring nations provided them with logistical sanctuaries. The planners also insisted on linking aircraft types to target sets. In other words, since strategic aviation had struck oil-related targets during World War II, it had to do it again. Tactical air power was definitely out of the question since it had not been used for strategic bombing in the past. In sum, the historical analysis points to a number of critical lessons which one must consider when targeting oil-related products and systems.

Building upon a historical foundation, the study then shifts its focus to current and future trends in both the oil industry and modern war. At present, it appears as though oil will feed the world's economies for at least the next 40 years and that consumption will continue to increase slowly. Technology, at the same time, appears to be accelerating the timing and tempo of war. Oil may very well be a critical target

in future conflicts and, in an era of "hyperwar," must be targeted for immediate effect. However, when targeting oil, one must not overlook the possibility of a protracted war. As a result, one should target tactical-level storage facilities first, critical resupply networks next, and refineries or points of importation last, when necessary. Finally, when targeting oil-related products, planners may want to consider the use of an entirely new series of weapons—nonlethal weapons. Nonlethal weapons offer the unique ability to degrade and/or eliminate traditional oil-based products vital to warfare without destroying a nation's infrastructure.

In sum, the petroleum-based sector of a nation's economy offers a large, vulnerable target for today's air planner. By merging the lessons of the past with current and future trends, one can achieve immediate results and dramatically affect the outcome of war.

About the Author

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Chapter 1

Introduction

As the last of the Japanese aircraft swept clear of Pearl Harbor, a large part of the US Pacific Fleet lay in ruins. However, despite the tremendous success of its attack, Japan had committed one of the greatest strategic mistakes in military history. Left intact, despite their vulnerability to aerial attack, were oil tanks holding four and one-half million barrels of oil vital to every American warship and airplane in the Pacific theater. In hindsight, the implications of the attack are obvious; the complex economic infrastructure required by today's military forces offers targets that are generally large, soft, and vulnerable. To protect or exploit such an infrastructure, one must understand its purpose, how it is constructed, and what are its vulnerabilities. As was the case more than 50 years ago, the petroleum-based sector of a nation's economy is a viable target deserving critical analysis.

The purpose of this monograph is to determine the fundamental utility of targeting the petroleum-based sector of a nation's economy. Although the sector impacts all areas of society, this study will first focus on how attacking petroleum targets in the past affected enemy military operations. Secondly, while modern history is full of examples of how to target and destroy an enemy's infrastructure, few attempts have been made to analyze the *why* of picking particular target sets. This paper will seek to correct this problem by analyzing whether petroleum will remain a critical resource in the future and, if so, how one might go about disrupting an enemy's access to oil, specifically refined petroleum products.

To properly analyze the criticality of petroleum to a nation and its military forces, one must turn back in time. Although one can look at numerous conflicts, this study will focus on the targeting of oil during World War II and Vietnam. Prior to World War II, little practical experience existed when it came to targeting national economic systems. In fact, only a handful of air theorists had given any serious thought to strategic targeting until the US Army Air Corps Tactical School and the British Air Ministry began to consider the problem in the late 1930s. During the course of the Second World War a variety of war plans, from AWPD/1 to the Spaatz "Oil Plan," identified oil as a primary target. In retrospect, its selection as a primary target was sound and provided a number of key lessons that are still applicable today. They include (1) the need for strategic intelligence; (2) the need for civilian experts to identify proper targets; (3) the realization that doctrine is more than targeting; (4) the realization that centers of gravity are not always subject to attack; (5) the need to anticipate the collateral effects of bombardment; and (6) the possibility of gaining air superiority by first targeting petroleum, oil, and lubricants (POL).

Twenty years later and half-way around the world, oil, along with many other strategic target sets of World War II, proved to be of little value in the Vietnam War. Whereas World War II was an unlimited war, Vietnam was a limited war fought in a nuclear age. Furthermore, the logistics sanctuaries provided by neighboring countries were often off-limits to attack. As a result, oil proved to be an elusive target of questionable value during Vietnam. While some of the targeting lessons learned during World War II still applied, air planners also had to learn and relearn another set of lessons. Some of the more significant ones included (1) the need to ask if oil is always a primary target; (2) the need to avoid mirror imaging; (3) the need to question if only certain aircraft can target certain targets; (4) the need to obtain and use effective tactical and strategic intelligence; and (5) the need to consider the possibility and ramifications of sanctuary. While this study will address each of these historical lessons, it will not attempt to solve each of the problems it raises.

Given the varying utility of oil in past conflicts, will it remain a valid target in the future? The answer is yes. Oil is not likely to be replaced by any alternative energy source in the near future. Cost alone will prevent the conversion to alternative energy sources. In terms of targeting, and as the recent Gulf War demonstrates, POL will remain a critical target in a new era of hyperwar. Since time is of the essence in hyperwar, it only makes sense to target oil for immediate effect. However, one must not overlook the possibility of protracted warfare. To address both long and short wars, this paper will suggest a flexible targeting scheme that can achieve immediate or long-term effects, as the situation requires. The idea is to strike tactical-level targets first for immediate effect, critical elements of resupply next, and the sources of refined petroleum products last, should the need arise. Finally, to aid future air planners, this study will present what appears to be the best target at each level of potential attack.

Ultimately, the fundamental purpose of this monograph is to assist future air planners in their analysis of single target sets. While refined petroleum products offer a distinct, and in many cases, critical target, they are by no means a panacea. Planners will want to merge the information presented here with other studies and sources to enhance their efforts. However, when doing so, planners must ultimately realize targeting theory is, and must be, considered an art shaped by personal bias, fact, and assumption.

Chapter 2

Unlimited War and Oil

Early Theory and World War II

War, by definition, is "an act of force to compel our enemy to do our will."[1] Assuming the goal remains the same, it logically escalates to a point where the enemy is forced to employ "the total means at his disposal and the strength of his will"[2] in an effort to resist. As adversaries commit further resources, one in an effort to force a change in behavior and the other in an effort to resist, they approach extremes. War, as it approaches these extremes, ultimately consumes a nation's entire resource base "in an everexpanding machine of violence"[3] defined as unlimited war. Given the technological advances during the 1920s and 1930s, the possibility of unlimited war continued to expand. The rise of air power, in particular, set the stage for unprecedented violence, as distant cities, factories, and economic infrastructures became targets. One of the most crucial of all targets was oil and its associated by-products.

Although the first major attempt to destroy petroleum or its byproducts did not occur until World War II, considerable interest in it as a potential target existed before the war. During the late 1930s, for example, the US Army Air Corps Tactical School (ACTS) advocated aerial attacks against a nation's "industrial web," or "national economic structure." Strategic bombardment enthusiasts like Haywood S. Hansell, Jr., Muir S. Fairchild, and Laurence S. Kuter thought that a nation's ability to wage war was directly related to its ability to convert raw materials into weaponry. Within this context, the petroleum industry became a prime target. As the 1939 ACTS "National Economic Structure" lecture noted:

> Petroleum is essential to modern war. Air Forces, mechanized and motorized forces, as well as navies would be helpless without its products. Should it be possible to deny oil to a nation, its ability to wage modern war would be seriously interfered with, if not completely terminated. Also this denial would cause a breakdown in the transportation and distributing system of the nation.[4]

The ACTS lecture stated that the petroleum industry was vital to the United States, that it was heavily dependent upon pipelines, water transport, and rail nets, and that refineries tended to concentrate in the same geographic area. The lecture also suggested that while the United States possessed a unique indigenous oil industry and a redundant distribution system offering sufficient cushion in case of attack, other nations were not as lucky and were highly susceptible to disruptive aerial attacks. The ACTS laid the ground-work for economic analysis and industrial targeting and advocated a strategic air power doctrine that would subsequently influence the American approach to aerial warfare and target selection in World War II.

At the same time, the British were also busy analyzing how best to destroy an adversary with strategic bombardment. In 1939, the British Air Ministry directed a series of "bottleneck" studies in order to locate the key points within important sectors of the German economy. The British sought "target sets containing only a few targets the destruction of which would have an immediate effect on the enemy's power of resistance."[5] To qualify as a "bottleneck," a target set had to be of major importance to a nation's military, have a substantial proportion of its total output concentrated in a few plants, have no appreciable spare production capacity in or out of the country, have only limited possibilities for its use within the economy, possess machinery which could not be quickly repaired or replaced, and be incapable of quick dispersal without great loss of production.[6]

Although oil was not included in the original target set,[7] a series of studies conducted during 1936 by the Industrial Intelligence Centre recognized it as a "bottleneck." As a result, the British incorporated oil, along with various other target sets, into a series of 13 prioritized war plans known as the Western Air Plans (WAP), which appeared on 1 October 1937.[8] While both WAP 5 and 6 dealt with oil, the latter was the basic oil plan and sought to destroy the core of German fuel production and supply—"14 synthetic oil plants and as many major oil refineries."[9] On 22 February 1940, Sir Cyril Newall, chief of British Air Staff, agreed that Bomber Command should attack oil targets in accordance with WAP 6 if Germany invaded the Low Countries. By mid-April 1940, the British Air Staff was convinced German oil stocks were desperately low and that any further reduction would force Germany into a crisis situation.

As expected, five days after the German invasion of the Low Countries in May 1940, Bomber Command began its oil campaign. The actual Western Air Plan used was W.A.4(c), which targeted oil plants in the Ruhr Valley (WAP 6). Oil remained the basis of Britain's offensive strategy throughout most of 1940 and continued to enjoy popular support. The *Future Strategy* report, issued by the British chiefs of staff on 4 September 1940, reflected the optimism of the time and stated that "Germany's oil stocks might be exhausted—and Germany's situation disastrous—by June 1941."[10] In reality, a lack of suitable long-range aircraft and a variety of competing target priorities[11] forced oil to become just one of several competing target sets to receive attention. It was not until May 1944 that it began to receive significant attention from Allied bombers. Up to that point, "only 1.1 percent of all Allied bombs had been directed at petroleum targets."[12]

What was it about oil that made it such a lucrative target? The answer lies in the targeting studies and analyses conducted during the war. The US Army War Plans Division submitted the first of the major target studies on 11 August 1941. Although entitled "Munitions Requirements of the Army Air Forces [AAF]," it was more commonly known as AWPD/1. Written by graduates and instructors of the ACTS, the plan reflected the school's teachings—that one should conduct precision attacks against critical points in an enemy's national economic structure in order to eliminate his ability to resist.

According to Haywood Hansell, one of the authors of AWPD/1,

> the overriding question was, which were the most vital links? And among these, which were the most vulnerable to air attack? And from among that category, which would be most difficult to replace, or to 'harden' by dispersal or by going underground?[13]

Critical to the mission set forth in AWPD/1 was the disruption of German electrical power and transportation systems, destruction of the German petroleum systems, and if necessary, the undermining of German morale.[14] In the case of oil, the AWPD/1 planners identified German synthetic oil plants as essential targets. The synthetic oil plants were responsible for 60 percent of the German aviation gasoline production. More specifically, 80 percent of the aviation gasoline came from 27 synthetic oil plants located in western and central Germany no more than 1,000 miles from English bases.[15] These 27 plants became the primary oil targets for American bombers. Over the next year, two minor plans (AWPD/4 and Plan for the Initiation of Air Force Bombardment in the British Isle) would list oil as a target before the next major war plan, AWPD/42, revised targeting priorities.

In August 1942, President Franklin D. Roosevelt asked Gen George C. Marshall for the "number of combat aircraft by types which should be produced for the Army and our Allies in this country in 1943 in order to have complete air ascendancy over the enemy."[16] The subsequent document, known as AWPD/42, set forth the "theoretical requirements" for complete air ascendancy in Europe and, along with the results of the bombing efforts to date, served as the basis for AAF strategic planning. While target priorities remained basically the same as earlier AWPDs, AWPD/42 established a clear breakdown of responsibilities. The Americans would pursue a daylight, precision bombing campaign against vital elements of the German war economy while the Royal Air Force (RAF) would continue its night, area bombing offensive in an effort to break enemy morale. Refined oil products became the fifth priority target behind the German aircraft industry, submarine building yards, transportation, and electrical power.[17] The plan called for the complete destruction of 23 synthetic oil plants and Romanian refineries, including Ploesti. The overall goal was a 47 percent reduction in refined oil products.[18] These goals, however, required current and accurate intelligence.

The creation of the Eighth Air Force in England reaffirmed the need for "strategic" intelligence in air targeting. While the Economic Objectives Unit (EOU) of the Office of Strategic Services, based in the American embassy in London, provided part of the solution, it was the Committee of Operational Analysts (COA) that had the greatest effect on targeting. Although political considerations prevented them from formally prioritizing their list of potential targets,[19] the COA's March 1943 report hinted at the priority of the over 60 targets by industry. The top three targets, seemingly, were fighter aircraft, ball bearings, and petroleum.[20] Both British and American economic authorities felt that few German oil stocks existed and that the petroleum industry was "a peculiarly concentrated target within practicable flying range."[21] In choosing oil, the COA agreed it was an indispensable and vulnerable target that had a direct relationship to Germany's capacity to resist invasion.[22] In reaching their decision, the COA

> considered (a) the indispensability of a product to the enemy war economy, (b) the enemy position as to current production, capacity for production and stocks on hand, (c) the possibilities of substitution for the product, (d) the number, distribution and vulnerability of vital installations, (e) the recuperative possibilities of the industry, (f) the time lag between the destruction of installations and the desired effect on the enemy effort.[23]

The COA's report on the *Western Axis Oil Industry*, dated 16 January 1943, rated the importance of petroleum-related targets as follows: hydrogenation plants, crude oil refineries, high-grade lubricant plants, coke ovens, Fischer-Tropsch plants, tetraethyl lead plants, and oil fields and pipelines.[24] Hydrogenation plants received top priority because they produced 30 percent of all oil and 80 percent of all aviation fuel available to Germany in 1943, they were favorably located, and they would be difficult and expensive to repair/rebuild. The COA listed crude oil refineries second due to the large number of targets (29 crude oil refineries versus 15 hydrogenation facilities), the distance and distribution of targets from Allied air bases, and because it was much easier to repair/replace a standard oil refinery than a hydrogenation plant. Although important, the COA felt the remaining targets offered little to the overall Axis effort. While certainly not infallible, the COA had brought together a group of experts able to dissect and examine the German war economy, helped focus Allied efforts, and set the stage for the Casablanca directive, the Trident Conference, and the subsequent bombing directive.

In an effort to determine future Allied strategy and refine muddied military policies, President Roosevelt, Prime Minister Winston Churchill, and the Combined Chiefs of Staff (CCS) met in Casablanca during mid-January 1943. Among the key issues discussed was how best to use the rapidly growing Allied bomber force. On 21 January 1943, the CCS released the now famous Casablanca directive, or CCS 166/I/D. German fighter strength became an immediate objective, followed by a prioritized list of primary objectives. They included German submarine construction yards, the German aircraft industry, transportation, oil, and other industrial targets. The directive went on to state that the order of priority might vary from time to time depending on wartime developments. The Americans saw no reason to change their original plans to destroy "submarine construction yards and bases, the aircraft industry, the ball-bearings industry, oil production, and, as secondary groups, the production of synthetic rubber and military transport vehicles."[25]

With the Casablanca directive in hand, the respective air forces spent the next couple of months translating policy into specific commitments and objectives. The plan for the "Combined Bomber Offensive from the United Kingdom," more commonly known as the CBO, became a reality with CCS approval during the Trident Conference in Washington during mid-May 1943.

It was the same plan which the Americans had adopted as a result of the COA report. It called for the destruction of 76 precision targets in six target sets.[26] Oil, as a vital industry, remained a primary objective; however, its status was contingent upon the ability to attack the Ploesti refineries from Mediterranean bases. Like AWPDs/1 and 42, the CBO called for a specific amount of destruction:

> The quantities of petroleum and synthetic oil products now available to the German[s] is barely adequate to supply the lifeblood which is vital to the German war machine. . . . If the Ploesti refineries, which process thirty-five percent (35%) of current refined oil products available to the Axis,are destroyed, and the synthetic oil plants in Germany whichprocess an additional thirteen percent (13%) are also destroyed, the resulting disruption will have a disastrous effect upon the supply of finished oil products available to the Axis.[27]

The last major push for oil as a target gained momentum during the spring of 1944 as the Allied forces prepared for D-day. Gen Carl A. Spaatz, commander of the US Strategic Air Forces, realized control of the air was critical for the success of the invasion. Since oil had become a precious commodity, Spaatz felt sure German fighters would rise to defend Germany's remaining oil facilities/stocks; when they did, American escort fighters would eliminate the Luftwaffe. Spaatz presented his plan to Gen Dwight D. Eisenhower on 5 March 1944.[28] He highlighted the "great strides the Germans were making in producing synthetic oil" and the fact that 90 percent of output came from 54 crude and synthetic oil refineries, of which 27 were critical facilities.[29] He went on to argue that if the 27 critical refineries were destroyed, half of the German gasoline supply would be eliminated, and that "if all fifty-four centers were attacked successfully, German oil production might fall to zero by September of 1944."[30] Although General Spaatz continued to lobby for oil, General Eisenhower decided in favor of the British "Transportation Plan,"[31] which promised immediate effects. However, Eisenhower gave Spaatz permission to attack German oil targets for a limited time.[32] The raids began in mid-May 1944, and as expected, "the German Air Force reacted vigorously to the attacks on oil plants and suffered severe losses."[33] Albert Speer would later say that "I shall never forget the date May 12. . . . On that day, the technological war was decided."[34]

Analysis of Oil Targeting in World War II

Although the decision to target oil seemed obvious, the reasoning behind it remains important today. In seeking to immobilize and eliminate the German military, Allied air planners did not just happen to seize upon oil. They narrowed their focus through a series of *specific questions* designed to identify the sources of military effectiveness. The questions, asked primarily by the British Air Ministry, the US Army War Plans Division, and the Committee of Operational Analysts, were as follows:

a. Which activities are most important to the military?
b. Which produce the most highly specialized products?

c. Which have the greatest degree of concentration?
d. Which are most difficult to repair, replace, or disperse?
e. Which offer no appreciable spare production?
f. What level of reserve stock is available to the enemy?
g. Is there any possibility of substitution?
h. Where and what are the most vital links?
i. Which links are the most vulnerable from the air?
j. Is time a critical factor?[35]

The case of German hydrogenation plants helps clarify the above process. The primary product of these plants, aviation gas, was critical to the success of the entire German military effort, particularly the Luftwaffe. It was a unique product produced by a limited number of highly vulnerable plants. In that "the hydrogenation plants were practically the sole source of Germany's aviation gasoline production," little spare production seems to have existed.[36] Furthermore, given the fact that all German pilot training had stopped by September 1944 and certain models of aircraft were grounded because of excessive fuel consumption, reserves appear to have been nonexistent and no other suitable fuel alternatives were available.[37] As for timing, it was a critical factor—the sooner the hydrogenation plants could be destroyed, the sooner air superiority could be won. Overall, while the above questions are somewhat general in nature, they helped Allied air planners decide that the German hydrogenation plants actually were important targets. The same questions offer a point of departure for the modern air planner, and an opportunity to narrow his focus.

The air planners of World War II were by no means ignorant, but they faced a series of new and difficult problems. Never before had there been a need for strategic targeting intelligence, for civilian expertise in target selection, or for an ability to understand the unanticipated effects of destroying particular target sets. Further, no one fully understood how to best defeat particular centers of gravity or gain air superiority by destroying a particular target set. Given the magnitude of these problems, further study and analysis now follow.

Although air planners did a fairly good job of asking the right questions about targeting oil, they suffered from a *lack of suitable strategic intelligence*. At no time in history had such a requirement for detailed industrial information ever existed. While the ACTS was aware of the need for industrial intelligence, as a concept it was still in its infancy.[38] A saving grace was the Committee of Operational Analysts, a group of primarily civilian experts who provided focus and direction to the strategic bombing effort by using economic and business principles to identify critical target sets. Given the relative success of the committee, future air planners should continue to *rely upon the services of civilian experts to help solve targeting and intelligence problems*.

Closely related to the problem of adequate intelligence is the fact that *doctrine is not necessarily a synonym for targeting*. Although the US Army Air Corps espoused a doctrine of unescorted, daylight precision bombardment, few airmen understood the relationship between doctrine and targeting. While early theorists had suggested particular target sets, none had gone into detail regarding what to strike, how to do it, and why. These problems were no different than the ones that challenge us today—*while our doctrine may appear sound, we are still at a loss, in many cases, of what to target and how best to do it*.

A third problem centered on *collateral effect and false causality*. While a lack of strategic intelligence obscured the collateral effects caused by lost oil, the problem only grew worse when air planners focused on the immediate cause and effect relationships that existed within single target sets. By focusing on single systems, the planners failed to consider the downstream effects on those who used petroleum by-products and chemical derivatives. In fact, it was not until after the war that the members of the United States Strategic Bombing Survey (USSBS) determined that by bombing the two largest hydrogenation plants, Ludwigshafen and Leuna, the Allies had eliminated 63 percent of Germany's synthetic nitrogen; 40 percent of her synthetic methanol, and 65 percent of her synthetic rubber.[39] According to the USSBS, "The oil, chemical, rubber, explosives, and other industries, in short, were interlocked not only by their mutual dependence on coal but also historically, geographically, and mechanically. . . ."[40] In other words, one simply does not have to strike a center of gravity to have an effect on it. Future targeting efforts must consider industry-wide cause and effect relationships, and the associated collateral effects of bombing key industrial systems, such as oil.

While oil should not be considered a panacea target, its role in total warfare must be recognized and understood. In World War II, *oil played a key role in the ability of various Air Forces to achieve and exploit air superiority*. Consider the case of the Luftwaffe, for example. Throughout the first half of the war, oil, among other things, allowed the Luftwaffe control of the air. By the time the Allies met in Casablanca, the German Air Force had become so strong that the Casablanca directive identified it as the immediate objective of Allied air forces. While the Allies worked diligently to destroy the Luftwaffe, it was not until mid-1944 that their combined efforts began to succeed. Once the Allies resorted to attacking German oil facilities, as suggested by General Spaatz (and the EOU), the Luftwaffe collapsed. Overall average oil production fell from 662,000 metric tons per month to 422,000 metric tons in June 1944 and 260,000 metric tons in December 1944. Aviation gasoline output fell from an average of 170,000 metric tons per month during the first four months of 1944, to 52,000 metric tons in June, and ultimately to zero.[41] Without aviation gasoline, the Luftwaffe was unable to protect the German economy, aid the Wehrmacht in the field, or continue pilot training.

The lack of aviation gasoline led to uncontested Allied air superiority over Germany and eventual defeat. There was a direct correlation between the amount of German aviation gasoline and Allied air losses. According to a postwar analysis done by the Stanford Research Institute, "The tight position of aviation gasoline was a major factor in the defeat of the German Air Force and its ability to protect. . . ."[42] Shortages of motor gasoline had equally disastrous effects as “tanks and armored vehicles were moved to the front by oxen”[43] and the Wehrmacht began to suffer dramatic reversals on both the Eastern and Western fronts. In sum, the Allied bombing of German oil targets caused a serious shortage of oil and its derivatives, resulting in the curtailment of pilot training; greater Allied command of the air, land, and sea; lower Allied attrition rates; and greater bombing effectiveness.

Summary

Oil was a vital target in the case of World War II and the rewards for effort expended were significant. Although “oil targets received [only] 234,806 tons or 15.9 percent of total [Allied] tonnage”[44] in Europe, the overall effect of the bombing was immense. Allied air power was able to gain and maintain air superiority as the Allied armies drove across the plains of Europe, overrunning the disintegrated German war machine. Ultimately, the war offered numerous lessons that are still applicable to air planners today. They include

1. the need for strategic intelligence,
2. the need for civilian expertise in target selection,
3. the realization that doctrine is not a synonym for targeting,
4. the recognition that centers of gravity are not necessarily subject to attack,
5. the need to anticipate the collateral effects of bombardment,
6. the ability to gain air superiority by targeting POL.

Chapter 3

Limited War and Oil

With the advent of nuclear weapons, war changed forever. Whereas entire nations had felt the pain and misery of total war in World War II, nuclear weapons now provided the means for at least one of the opponents to avoid such agony. Yet, the same immense destructive capability that allowed one to shortcut the road to unlimited war also served to deter unlimited war. Whether by accident or design, the US adopted the concept of limited war during the Korean conflict by withholding the use of nuclear weapons and respecting the right of sanctuary. From the Korean War on, all wars which have involved a country possessing nuclear weapons have been limited. Four major characteristics of limited war apply to our study of oil: what is limited for one party may be total for another; limited wars may be very costly and prolonged; prolonged limited wars generally enjoy much less public support than other types of war; and when the US fights a limited war, the limitations imposed generally increase the duration and cost of the war.[45] Consequently, as war becomes limited, the role of petroleum and its associated by-products must change as well. To study the role of petroleum in limited war, this paper will now focus on the Vietnam War.

Vietnam War

Following the Korean War, concern regarding the growing threat of communism continued to build in the Far East. In an effort to stem its further spread throughout Southeast Asia, the United States chose to make a stand in Vietnam. The objective of the US intervention, according to the March 1964 National Security Action Memorandum (NSAM) 288, was "a stable and independent noncommunist government."[46] In blending the goals of NSAM 288 with what they thought most appropriate, the Joint Chiefs of Staff (JCS) sought "to accomplish destruction of the North Vietnamese will and capabilities as necessary to compel the Democratic Government of Vietnam [DRV] to cease providing support to the insurgencies in South Vietnam and Laos."[47] The resulting air campaign, code-named Rolling Thunder, sought to reduce North Vietnamese assistance from external sources, destroy war resources already in North Vietnam (NVN) contributing to the support of aggression, and to harass, disrupt, and impede the movement of men and materials to Laos and South Vietnam (SVN).[48] Although not specifically mentioned, it certainly appears that the air planners were aware of the problem associated with sanctuary and dispersal.

> The American plan was to escalate the bombing gradually in an effort to weaken North Vietnam's will to resist by destroying its capability to fight. As a result, the military planners chose what they considered to be key sources of military and economic power as primary targets. In retrospect, it appears the planners chose many targets simply because they had worked in World War II. As in Korea, the planners were guilty of mirror imaging and failed to understand the kind of war they were fighting. Three criteria proved fundamental in choosing targets, they were (a) reducing North Vietnam's support of communist operations in Laos and South Vietnam, (b) limiting North Vietnamese capabilities to take direct action against Laos and South Vietnam, and finally (c) impairing North Vietnam's capacity to continue as an industrially viable state.[49]

In true Clausewitzian fashion, it was the political objectives, not the military objectives, which drove the actual decision to bomb North Vietnamese targets. Three fundamental considerations influenced target selection: "the value of the target, the risk of US pilot loss, and the risk of widening the war. . . ."[50] Consequently, when Rolling Thunder began on 2 March 1965, a majority of the previously identified POL targets were off-limits due to geographical constraints imposed by President Lyndon Johnson.

As President Johnson expanded the ground war in the summer of 1965, the JCS once again sought to increase the air effort. In August 1965, they submitted a revised plan calling for (1) attacks against military installations in Haiphong and Hon Gay, the mining of ports, and raids on roads and rail lines north of Hanoi; (2) further attacks on airfields, SAM sites, and other military facilities in Hanoi; and finally (3) POL storage areas and electrical power stations, followed by raids on the remaining industry in Hanoi and Haiphong.[51] In targeting POL, the JCS hoped to reduce the DRV's capability to provide transportation to the general economy and further complicate the logistical problems of moving troops and military supplies south. However, driven by conflicting political objectives, such as the need to end the war quickly while preventing Russian involvement, Secretary of Defense Robert S. McNamara refused to back the JCS plan. As a result, American flyers attacked only 126 of the 240 JCS proposed targets by the end of October 1965.[52]

On 3 November 1965, Secretary McNamara recommended an evolving Rolling Thunder campaign that would take five months and conclude with raids on POL storage areas and the mining of Haiphong harbor.[53] Frustrated by the lack of action, the JCS recommended "an immediate acceleration in the scale, scope, and intensity of the bombing, beginning with heavy strikes against POL targets. . . ."[54] The rationale was that if the rail lines could be successfully interdicted, trucks and motor-driven watercraft would play an even greater role in the delivery of supplies to the South. Then, if the supply of POL required by the motor-driven vehicles could be eliminated, the flow of supplies would dramatically slow, or stop, and the insurgency would wither and die.

Supporting their case was the fact that North Vietnam possessed no oil fields or refineries, and had imported 170,000 metric tons of oil in 1965, mostly through Haiphong. The tank farms at Haiphong, holding some 72,000 metric tons, appeared to be the critical link in the system. With 13 sites comprising 97 percent of North Vietnamese POL storage capacity, four of which had already been destroyed, the JCS convinced themselves that the destruction of the Haiphong tank farm, along with the eight remaining major storage areas, "would be more damaging to the DRV capability to move war-supporting resources . . . than an attack against any other single target system."[55] However, current intelligence indicated that numerous small POL storage sites were beginning to appear along with considerable drum storage capabilities. If POL was to be a suitable target, timing was critical so as to preclude the mere disruption of the supply system.

Following the unsuccessful attempt to negotiate a peace settlement during the 37-day bombing halt in the winter of 1965–66, support for POL strikes began to grow, and on 31 May 1966, President Johnson finally authorized air strikes against six small POL storage facilities in lightly populated areas. By mid-June, the President's advisors had convinced him to strike remaining POL targets, including the Hanoi and Haiphong oil storage facilities. The strikes began on 29 June 1966 and continued through July and August until the futility of the effort became clear. Although 70 percent of North Vietnam's large bulk storage had been destroyed, the enemy still possessed a significant cushion, most of which was located in off-limit areas found within North Vietnam.[56] As the summer wore on, North Vietnam continued to import and disperse oil at small scattered sites, and in quantities sufficient to meet her wartime needs. According to the Defense Intelligence Agency (DIA), "The greater invulnerability of dispersed POL meant an ever mounting US cost in munitions, fuel, aircraft losses, and men. By August we were reaching the point at which these costs were prohibitive."[57] The final blow to the POL campaign came on 30 August 1966 with the release of the Jason Summer Study report entitled "The Effects of US Bombing in North Vietnam." The study, by 47 of the nation's top scientists, stated that North Vietnam was "basically a subsistence agricultural economy that presents a difficult and unrewarding target system for air attack."[58] It further estimated that only 5 percent of the North's overall POL requirement was necessary for logistics flow to the South, thus suggesting that the air campaign could not possibly achieve its goal.

All in all, the US attempts to destroy the North Vietnam's POL stocks can be classified as a strategic failure. Both CIA and DIA confirmed the failure of the POL raids in a joint report, stating that "there was no evidence of insurmountable transport difficulties from the bombing, no significant economic dislocation and no weakening of popular morale."[59] US planners had greatly overestimated the North's dependence on the port facilities at Haiphong. After US bombers destroyed the dock facilities, oil tankers simply off-loaded their cargoes into waiting barges, which dispersed the POL among concealed storage sites along waterways. When bulk POL became a problem, the North Vietnamese simply switched to oil drums, making dispersal easier, faster, and more efficient. Simple innovation reduced their reliance upon vulnerable storage and distribution facilities. According to Adm U. S. Grant Sharp, commander in chief, Pacific Command (CINCPAC) and the operational director of Rolling Thunder:

> By the end of September and despite the heavy emphasis on this campaign, it was estimated that at the normal rate of consumption, North Vietnam retained sufficient reserves of POL to maintain its military and economic activity for up to four months.[60]

By the fall of 1966, US military leaders had given up any hope of oil being the critical link in the North Vietnamese infrastructure and subsequently shifted their attention to other industries and electrical power. Six years later, a final short, but intense, bombing campaign ended the US participation in the so-called limited Vietnam War.

Analysis of Oil Targeting in Vietnam

Many of the problems which plagued air planners in their attempts to target oil during World War II appeared during Vietnam. While the previously encountered problems were significant, the air planners of Vietnam either faced entirely new problems or made the same mistakes as their predecessors. All is not lost, however, as detailed study of these problems only serves to aid future planners.

Unlike World War II, where war was fought in all three mediums and few sanctuaries existed, North Vietnam basically fought a ground war without heavy equipment while enjoying the support of China and the Soviet Union. Whereas the Allied forces in World War II sought to immobilize and eliminate Axis military forces by targeting oil, the goal in Vietnam was to reduce external assistance, destroy existing oil resources, and disrupt the flow of war material to the south. Given the type of war fought in Vietnam, *the first question one might ask is whether oil was even necessary.* Did North Vietnam actually have a significant requirement for oil or its by-products? Secondly, how about collateral effects—could the Americans hope to affect other industries dependent on oil? The answer appears to be no. In the case of Vietnam, the North Vietnamese were basically supporting an insurgency, had few fielded forces, and enjoyed in-country, off-limit areas as defined by the United States. Further, the communists' POL requirements were small. According to one report, only 5 percent of the North's overall POL stock was necessary for logistics flow to the south.[61] Even after 70 percent of the large bulk storage in the North was destroyed, it had and maintained a significant cushion.[62] So, if the need for oil simply did not exist, why did the Americans target POL? The answer is simple—the planners were guilty of *mirror imaging.* What worked in World War II was sure to work in Vietnam, or was it?

Mirror imaging was not the only problem. *Air planners also sought to link particular aircraft to certain target sets.* Since strategic bombers were part of the Air Force arsenal, why not use them to strike strategic targets like oil? This erroneous coupling of "strategic" aircraft with "strategic" missions only served to further aggravate a faulty division of labor. However, in defense of the planners, one cannot simply overlook the influence of history. In the case of Vietnam, *the* historical example involving strategic bombing remained World War II. Planners are only now just beginning to resolve the issue of "tactical" versus "strategic" targeting due to technological advancements and the desire and ability to expand weapon system employment beyond traditional horizons.

Even if the planners were able to overcome the need to link an aircraft with a target, they still *lacked accurate and timely strategic targeting intelligence.* Following our rapid demobilization after World War II, the US intelligence community focused primarily on the greatest potential threat, the Soviet Union, and basically ignored the rest of the world. Furthermore, not only were the planners unprepared for a low intensity conflict, but they also failed to properly analyze the enemy. Unlike the Germans in World War II, the North Vietnamese were culturally different. Whereas the Germans possessed similar military capabilities and like consumption habits, North Vietnam possessed less hardware and a frugal people. Although the US intelligence community has made tremendous progress, more is required. Given the unique unipolar environment of the world today and the ever-increasing possibility of low intensity conflict and peacekeeping operations, the intelligence community must focus its efforts on potential "hotspots" versus traditional enemies. The final lesson of Vietnam deals with the *issue of sanctuary.* Sanctuary, by definition, is a place of "immunity from arrest or punishment,"[63] acccording to Bernard Brodie, it is a "self-imposed restraint."[64] Unlike Germany, North Vietnam enjoyed the benefits of sanctuary. In the case of North Vietnam, not only did China serve as the sanctuary, but the US actually declared certain areas within North Vietnam off-limits. The US was willing to recognize sanctuaries in an effort to keep hostilities from escalating to unlimited warfare. As for cost, not only were communist forces and industry able to operate in a safe environment, but the targeting and destruction of supplies became more difficult and much less efficient. In the case of oil, not only were the extraction and production facilities safe, but the devastating collateral effects enjoyed during World War II were no longer available. The only way to eliminate oil, or any other item for that matter, was to somehow interdict it before it arrived for end use. While the recent Gulf War demonstrates how effective interdiction can be, history offers numerous examples of how difficult it actually is, i.e., operations on the Ho Chi Minh trail. Yet, one must realize that sanctuary is not always negative. For instance, Haiphong was a critical link and natural "bottleneck" in the case of Soviet sanctuary and resupply. Had the US not voluntarily put Haiphong off-limits, the effects of sanctuary might have been greatly reduced. As frustrating as sanctuary may be, planners must be ready to plan around them in the future.

Summary

While World War II proved frustrating, Vietnam seemed to prove even more so. Not only did American planners fail to consider the lessons of World War II, they also sought to employ air power in inappropriate ways. While air power possesses many unique qualities and offers many unique capabilities, certain limitations do exist. Unlike Germany where the Allies were able to recover from an initial shortage of air assets, the Americans ultimately lost the Vietnam War with a preponderance of air power. Although no guarantees exist, the proper combination of targeting, air assets, and timing may have worked in Vietnam. In leaving this study of limited war, one must remember to consider whether attacking oil is even necessary; the dangers of mirror imaging; the false coupling of “strategic” aircraft with “strategic” targets; the requirement to obtain and use accurate, timely intelligence and technical expertise; and finally, the constraints introduced by sanctuaries.

Chapter 4

Hyperwar and the Future

In planning for the future, one logically seeks to use past experience and current information. This study of oil is no different. By now, the reader might realize the utility of targeting oil during total war, but may question its utility as a target during limited war. In considering oil as a future target, this paper will now focus on the projected availability of oil, expected future consumption patterns, and the possible use of alternative energy sources. It will then examine the current trends and future direction of air warfare and merge the results of the two. After proving the continued importance of oil in future war, the study will tackle the difficult question of whether or not it is possible to effectively target oil during hyperwar. While the answer appears to be yes, a target priority system is vital, given the need for immediate results. Finally, this paper will provide an overview of what the typical POL infrastructure looks like and how one might target oil most effectively.

Projected Availability and Future Consumption

Oil is and will remain a viable world energy source for the foreseeable future. As of 1 January 1992, known world crude oil reserves stood between 967.1 to 989.4 billion barrels.[65] As for consumption, in 1991 the world consumed 66.6 million barrels of petroleum per day, with four countries consuming more than 50 percent of the total.[66] Given the current consumption rate, existing crude oil reserves should last more than 40 years. However, many believe a variety of factors will allow for the continued consumption of oil well beyond the 40-year point.

According to Dr Charles D. Haynes, professor of Mineral Engineering at the University of Alabama, we can expect to use oil for another 150 to 200 years. Haynes believes that current oil reserve figures fail to consider vast Russian oil reserves, that Middle Eastern oil reserves are generally understated, and that alternative sources of energy, such as natural gas, will continue to grow in use and demand.[67] It seems reasonable to assume that as advances in efficiency and conservation efforts continue and alternative energy sources replace the existing demand for petroleum-based products, the availability of oil will be extended even further into the future. Although consensus is difficult to achieve regarding the future availability of oil, it appears that oil will be available for more than 40 years, given revised oil reserve estimates, changes in consumption habits, and the availability of alternative energy sources.

One of the keys to not only predicting the availability of oil, but to targeting petroleum-based systems as well, is future consumption trends. Although each person in an industrialized nation consumes as much as 10 people in a developing one,[68] it appears as though consumption will increase much faster in developing nations than in mature Western economies. A report by the World Resources Institute states, “A further tripling of energy demand in developing countries is expected between 1985 and 2025, with fossil fuels such as oil expected to be the major energy source.”[69] The same report goes on to confirm rapidly improving energy efficiencies among Western industrialized economies, while the International Petroleum Encyclopedia states that demand among developed nations should increase at about 1 percent per year, with overall demand lower in 2000 than it was during the peak year of 1979.[70] Furthermore, industrialized nations enjoy certain advantages, like redundancy and nonessential consumer production, which allow for greater sacrifice and substitution during war. In sum, while world oil consumption is increasing, the trend is generally lower in industrialized versus developing nations.

Alternative Energy Sources

Since this study is concerned with how best to disrupt oil use and consumption, and primarily that of enemy military forces, a brief discussion of possible alternative fuels is necessary. In the case of motor vehicles, alternative fuels appear to be a real possibility. Gas condensate, the unrefined liquid recovered from natural gas or tar sands, gilsonite and oil shale, can serve as a suitable alternative for stationary turbine and motor vehicle engines. Offering even greater potential are natural gas, compressed natural gas (CNG), and propane. At present, while it is possible to design an engine which can burn any of the above mentioned fuels, designing a suitable fuel storage and injection system which allows a vehicle to run on either basic gasoline and an alternative fuel is a different story. In doing so, one must dramatically increase the size of the vehicle. Finally, a number of other synthetic fuel processes exist, such as direct coal liquification, but the lure of cheap oil has made their development economically unattractive. While alternative fuel sources exist for motor vehicles and gas-powered engines, a variety of factors will determine conversion rates, to include external threats, alternative fuel availability, and competing demands for limited funds.

As for piston and turbine aircraft engines, the story is somewhat different. Piston engines are the more rugged of the two and burn a fuel with low spontaneous ignitability called aviation gasoline, or avgas for short. Although similar to motor gasoline, avgas is fairly expensive and is only produced in certain refineries through batch production.[71] Turbine engines, on the other hand, require fuel with a specific carbon content designed to “limit flame radiation, carbon deposition and the formation of smoke.”[72] The turbine fuel, commonly known as aviation kerosene, is relatively easy and inexpensive to produce. Unlike motor transportation, for which alternative fuels are available, there is no readily available fuel substitute for aircraft engines.

Further, in the case of aircraft engines, the driving factor for alternative technology is cost. Piston engines can, in fact, use liquid methane or avgas produced through coal liquification. Turbine engines can also use a similar coal-liquification derivative, liquid methane, or liquid hydrogen. In addition, biofuels, electric, and nuclear propulsion all enter the picture as suitable alternatives to petroleum-based aircraft propulsion systems. However, regardless of engine type or alternative fuel, the problem remains the same. As long as crude oil prices remain reasonable, the cost of converting aviation to alternative energy sources will remain prohibitive.

Current and Future Trends in Warfare

Given the relative availability of oil for the foreseeable future and its importance at the conventional level of war, one must next consider the future of war itself. Assuming the recent Gulf War is an indication of things to come, rapid and revolutionary developments in technology are creating a new and highly effective form of warfare. This new form of warfare, entitled hyperwar,

> capitalizes on high technology, unprecedented accuracy, operational and strategic surprise through stealth, and the ability to bring all of an enemy's key operational and strategic nodes under near-simultaneous attack. Hyperwar is very difficult to defend against or to absorb. . . .[73]

The goal of hyperwar is strategic paralysis. The latter, as defined by Maj Jason B. Barlow, author of *Strategic Paralysis*, "is to selectively attack or threaten those targets that most directly support the enemy's ability or will to continue with his current behavior."[74] Given the relative importance of oil, the question then becomes one of timing. Is it possible to target oil in such a manner so as to support the desired outcomes of hyperwar, and if so, how does one go about doing it? To answer the question, a quick analysis of the Gulf War is in order.

At first glance, it appears as though one can target oil and affect the outcome of hyperwar; however, such a conclusion actually requires further study. During the strategic phase of the air campaign,[75] air power sought to inflict a "state of paralysis spreading throughout the infrastructure, and in doing so, eliminate Iraq's capability to continue subsequent operations."[76] The air planners ultimately selected eight target sets to accomplish their objectives.[77] While oil appeared seventh on the list, its relatively low standing can be misleading since oil and electrical power are considered "organic essentials," or in other words, those facilities or processes without which the state or an organization cannot maintain itself.[78] Even minor damage to organic essentials may make "it physically difficult or impossible to maintain a certain policy or to fight."[79]

Mindful of the role of organic essentials, commanders issued very specific instructions. Allied aircraft were to destroy Iraqi oil refining and distribution facilities, but not long-term production capabilities.[80] According to the USAF

Report, *Reaching Powerfully, Reaching Globally,* Coalition oil targets included only Iraq's "militarily significant refined product production, and not its crude oil production facilities."[81] The goal was to eliminate the flow of POL to Iraqi military forces without causing any lasting damage to the nation's economy. Ironically, refineries tend to be one of the POL-related targets requiring the greatest amount of time to rebuild.[82] In all, the coalition air forces struck 28 Iraqi refineries and major storage facilities with an average of 43 tons of bombs per refinery.[83] By day 34 of the air war, Iraqi refining capability was down some 93 percent, with 20 percent of the fuels/lubricants at the refineries and major depots also destroyed.[85]

By targeting oil specifically, the planners hoped to slow Iraqi POL production, eliminate the possibility of resupply, and force senior Iraqi leaders to stop further offensive action at the strategic level. As in previous historical examples, the big question was how best to measure the effects of knocking out a critical system, particularly since the effects are interpreted differently by all. Further compounding the problem was a lack of cross information (i.e., an understanding of the collateral effects of eliminating a particular system).[85] The planners also had to assume that the major components of Iraq's petroleum industry were basically the same as other systems worldwide, and that they were organized as "hub and spoke" type systems.[86] The fact the planners had to assume anything indicates a potential problem—peacetime target study and intelligence gathering remains essential.

In summarizing the effects of the Coalition air attack, the official Air Force report states, "The oil campaign was as decisive as it had been in World War II, but in a shorter time, with greater effectiveness, and with incomparably fewer losses."[87] While the latter half of the statement appears credible, the issue of decisiveness is certainly open to debate. It seems possible Saddam Hussein may have adopted a strategy of inaction during the Gulf War, choosing to husband or disperse his aircraft and maintain a stationary army of occupation in Kuwait. In actuality, the mere fact that he did not move or use his military as one might expect makes it impossible to determine just how effective oil targeting might be during hyperwar. In sum, the overall utility of targeting oil during hyperwar remains unknown.

Although the pace of war has accelerated, planners cannot simply discount the possibility of a protracted war. They must consider and plan for not only immediate results, but for prolonged warfare as well. To adequately merge the changes in warfare with the utility of targeting POL and related facilities, one must adopt a "user first" model of targeting.[88] In explaining the model, one must first realize that, given the pace of hyperwar and the elasticity of supply networks,[89] *immediate results are a must.* In the case of oil, such results occur at the tactical level. For instance, by destroying the jet fuel at a given base, all aircraft which are unrefueled at the time of attack immediately become ineffective. As the war lengthens in duration, the enemy will obviously attempt to repair damage and resupply the base. While previously struck targets require monitoring, and in some cases follow-up sorties, one's efforts should next expand to enemy resupply capabilities. *Repair without* *resupply is useless*. Finally, if the war becomes protracted, planners may want to consider attacking long-term, dual-use targets.[90] It is at this point that production enters the picture. Given sustained military operations, the destruction of refineries or oil importation points may be necessary to eliminate any chance of resupply. However, in doing so, the source of petroleum products consumed by the civilian sector will most likely also be destroyed. Although relatively straightforward, this targeting model accounts for varying durations of war and maximizes one's awareness of morality during warfare by striking pure military targets first.

The Typical POL Infrastructure

Given the unique dependency of military forces on petroleum-related products and our ability to easily eliminate critical portions of the oil production system, an understanding of the POL system and how to target it is appropriate. One should first note that the industry is shaped somewhat like an hour glass. A vast number of oil wells feed a limited number of specialized refineries which in turn feed tremendous consumer demand. Crude oil itself, like many other raw materials, is of little value until it passes through a refining process. In other words, the crude oil refining process is a potential bottleneck within the industry. As for targets upstream of the refinery, they are of little value as raw crude can be obtained from a variety of sources.[91] Furthermore, whether a country is a net importer or exporter of crude oil matters little if they have no refining capacity. Sitting upon millions of barrels of oil is of little value unless you can process it into a useable product or sell it on the open market—Iraq serves as a prime example. Unlike the infrastructure upstream of the refinery, the portion downstream of the refinery offers tremendous targeting potential.

Following the refining process, consumer products are generally only stored while awaiting shipment to end users. Storage, whether at the refinery or prior to ultimate use, can take place in a variety of forms. Surface bulk, underground bulk, and floating storage are the most commonly used methods.[92] As for transportation, a majority of refined products tend to move by pipeline. Trucks, railroads, and ships play a relatively minor, but important role. Final storage and distribution is basically the same as above, but uses primarily trucks and pipelines.

What To Hit?

Targeting at the tactical level becomes a question of what to strike. Whereas other methods either kill essential personnel or destroy expensive assets that US or Coalition leaders may want left intact for political reasons, the destruction of bulk fuel storage is relatively simple and cost-effective. For the most part, fuel storage is a matter of containment and transfer capability. One either destroys fuel stocks and storage facilities or the capability to move the fuel.[93] Common sense dictates one should target the fuel itself and eliminate not only existing fuel reserves, but the ability to store new fuel stocks when they arrive. Without storage capability, resupply is of little value.[94] By destroying the average wing's fuel reserve, usually a minimum of 30 days, there is very little an already strained logistics network can do to meet the demand, particularly during war. (ACC peacetime consumption rates generally average between 200,000 to 300,000 gal/day, with a surge rate exceeding 400,000 gal/day.[95] As for moving fuel, the destruction of pumps and associated plumbing networks is of little use at the tactical level since alternative methods of transfer and refueling exist. The typical base can extract and move fuel in a matter of hours.[96] Without storage capability, however, an airfield or logistics depot is of little use to combat forces.[97]

As for targeting itself, two options exist. Since the ultimate goal is to eliminate existing fuel reserves, the target of choice is the actual storage tank itself. Storage tanks have historically been difficult to destroy due to the precision required to hit and penetrate the target. However, with the advent of advanced precision munitions, the task is much easier.[98] One must also be aware of the fact some bases possess greater dispersal capability than others. For instance, while one base might disperse its 2,000,000 gallons of fuel between five different locations, another might only have two dispersal locations at its disposal. The second option is to target the pumphouse associated with the tank itself. "A direct hit or even possibly a near miss on a pumphouse could result in a fire. A fire on a large POL storage tank could last for several days."[99] When planning, one must also look for additional holding tanks close to, but not necessarily on the airfield or logistics base. Such tanks are generally found within a 10–15 mile radius of the base.[100] The bottom line—target tactical level storage facilities first.

While destroying tactical level fuel supplies certainly hampers operations, it may not force immediate enemy capitulation. Should this be the case, an enemy will most likely find himself in one of two positions—either collapsing onto internal lines of communications (i.e., retreating toward friendly territory) or engaging in static defense. In either case, fuel will be necessary, and since local reserves have already been destroyed, resupply becomes critical. Since resupply is so important, it must logically become the next, or intermediate, level of targeting. The actual resupply is simply a matter of movement, and in the case of POL, it takes place through a series of pipes, ships, and vehicles. In reality, the destruction of POL resupply capability is no more than a form of interdiction.

Pipes are certainly the most efficient and effective, and in many cases the only, form of resupply. As of 1990, 442,974 miles of pipeline existed in the United States including the world's largest volume petroleum pipeline, the Colonial pipeline system, which stretches from Texas to New York Harbor.[101] In 1991, it delivered 659.8 million barrels of refined petroleum products to a variety of users including major civilian and military airports, such as Atlanta, Dulles, National (Washington, D.C.), and Andrews Air Force Base.[102] In fact, the Colonial pipeline carries some "15.8 percent of all gasoline, kerosene and fuel oil supplied to the nation. . . ."[103] The United States is not the only country dependent upon pipelines; the world is replete with examples of pipelines that are critical to wartime resupply which may be a prime target after the destruction of tactical level fuel storage facilities.

Pipelines are very similar in design. They consist of main and spur lines (both are usually buried), injection stations, booster stations, delivery facilities, breakout storage, and computerized control facilities. Fuel can be rerouted through branch pipelines when problems develop and emergency response teams are readily available for routine disruptions, such as breaks, ruptures, or pump failures.[104] Alternate control facilities and manual operation can replace centralized computer facilities, but in a much less efficient manner. In some cases, truck or rail can provide an alternative means of transportation for small quantities over short distances.[105] Given the possible fixes to pipeline disruption, the question becomes, how best to stop the flow of oil through a pipeline?

The process of pipeline disruption is a relatively simple one. Although numerous alternatives exist, the one showing the greatest promise is the elimination of pumping capacity. According to the Defense Civil Preparedness Agency, a "pipeline has its greatest vulnerability at its unguarded and unmanned pumping stations."[106] A more recent General Accounting Office (GAO) report agrees and states, "Although industry is capable of quickly repairing minor damage—such as breaks in pipe—the time to repair complex facilities, such as pump stations, may extend to six months or more."[107] The explosion and fire which destroyed Pump Station Number Eight on the Alyeska (Trans Alaskan Pipeline) pipeline confirm the findings of the GAO report. Throughput dropped from 1.2 to 0.7 million barrels per day, and despite an intense rebuilding effort, it took more than nine months to rebuild the station.[108] Finally, a 1970 Stanford Research Institute report indicated that by destroying only three pumping stations along the Colonial pipeline, it would be possible to cripple or halt its use.[109]

Pipelines, and specifically pumping stations, suffer from inherent vulnerability as a result of exposed, unguarded facilities; computerized operations; a limited number of experienced personnel; lack of available spare parts; and a glut of readily available public information on pipeline operations.[110] One of the best examples of this vulnerability is the Colonial pipeline, which is a model for other large systems throughout the world.[111] According to Mr Dode Edmonds, manager of Operations Planning and Pipeline Control for the Colonial Pipeline Company, the loss of only two booster stations along the pipeline would result in pipeline shutdown.[112] Target identification would be no problem since most of the pumps and motors are located outdoors at remote, unmanned sites along the pipeline. Furthermore, not only are the pipeline and pumping station locations readily available through open sources, but the pipeline and booster stations are also easily identifiable with infrared overhead photography.[113]

In targeting booster stations, one can expect to put the pipeline out of commission for at least 20 weeks.[114] One should note that while Colonial uses some of the largest pumps in the world (5,000 horsepower [hp]), it is possible to run a series of smaller pumps together. However, as Mr Doner of BWIP's

Pump Division says, "this type of arrangement is generally not very effective."[115] One should also realize that pump size is often a function of pipeline size. In other words, the smaller the pipeline diameter, the smaller the pump required, and the smaller the pump required, the easier it is to obtain and replace.

Another item worthy of mention is the need for electrical power—each 5,000 hp motor and pump requires approximately 3,750 kilowatts of electricity. Although the demand is fairly large, packaged systems (i.e., portable generators) are available to replace damaged electrical grids. Finally, while it might be possible for Colonial to move spare pumps from each of its remaining operational stations, such an effort would require extensive plumbing and transportation assets, not to mention the time to rebuild the original booster station.[116] Once a pipeline is back in operation, a certain delay in oil delivery will occur since it only travels at about four miles per hour when the pipeline is fully operational. In sum, pipelines are prime targets. While minor repair capabilities exist, pipeline operations can be easily shut down for a significant period of time.

Finally, in the case of protracted war, one may have to resort to a final, or strategic, level of targeting. It may be necessary or desirable to attack the actual source of a petroleum-based product—the refinery or point of entry into the country. In those cases where few or no refineries exist, a country will have to import refined products. Regardless of how the product arrives, it will most likely enter a pipeline for distribution, and possibly some form of storage, before end use; when it does, it becomes a resupply target. When discussing product importation, two additional items warrant attention. First of all, if the product arrives by truck or rail, the planner will have a case of simple interdiction on his hands. Second, if the product arrives by ship, the planner may have a problem since it may be politically and environmentally incorrect to sink a fully laden supertanker. Once empty though, a majority of the environmental problems disappear and the tanker may become a prime target. Sinking an empty tanker at either the terminal, or in a channel, may deny use of vital facilities to other ships and eliminate the potential for resupply. The obvious alternative is to actually destroy the marine terminal itself. Iraq's Mina al-Bakr oil terminal, located on the northern tip of the Persian Gulf, serves as a prime example of how vulnerable a terminal, pipeline, and pumping network actually is. During the Gulf War, the facility was 90 percent destroyed. It subsequently took "a record" eight months to rebuild the facility using Iraqi know-how and engineering personnel.[117] (One should note, however, that reconstruction did not actually start until 10 months after the war ended. The terminal was out of service a full year and a half.[118]) While targeting importation points is important, most of the countries who might wage a full-scale war possess refineries which produce a majority of their fuel requirements.

Although targeting refineries seems like a simple matter, it can be a very precise art. It is not necessary to completely destroy an entire refinery, or in some cases, to even target a particular refinery. Each refinery is different and generally built to process a particular type of crude oil or to produce certain products driven by market demand. For example, a refinery will generally process either sweet or sour crude, or low versus high API crude; it may be built around a specific method of processing (distillation, cracking, visbreaking, coking, etc.); and it might be designed to supply a particular product (i.e., avgas). Furthermore, refineries typically fall into one of three categories: (1) topping plants (basic distillation units), (2) hydroskimming plants (distillation and catalytic hydrotreating and reforming facilities), and (3) cracking plants (hydroskimming units plus "crackers").[119] As refineries grow in size, they tend to acquire the ability to alter production to meet changing consumer needs. Thus, when targeting oil refineries, a planner must know what the specific goal is (i.e., to stop the production of fuel oil for example). Once the specific goal is known, a petroleum engineer or expert will be able to tell the planner exactly which refineries must be struck and where.[120]

The where of a refinery attack is a relatively simple question to answer. Although refineries tend to come in all different shapes and sizes, known as configurations, the actual refining process is basically the same. The first step, and primary refining process, is called distillation.

> Distillation involves the separation of the different hydrocarbon compounds that occur naturally in a crude oil, into a number of cuts or different fractions. Heated crude oil is separated out in a distillation column or fractionating tower into streams which are then purified, transformed, adapted and treated in a number of highly complex subsequent refining processes. . . .[121]

Distillation takes place in atmospheric distillation columns or fractionating towers and can yield some lighter end products (straight run gasoline) of diminished quality. The remaining heavy fuels and residues are further broken down into lighter, more usable compounds with heat, a catalyst, and pressure. This process is known as cracking.[122] Catalytic cracking is the most common form of cracking.[123] In most cases, the heavy feedstock enters the "cracker" or "reformer" where the basic chemical structure of the hydrocarbon is modified with heat, catalyst, and pressure. As in the case of distillation, cracking and reformation take place in tall, high-pressure vessels also known as towers. Following the reformation process, remaining impurities are extracted; special, but generally nonessential, compounds added; and the various cuts are mixed and blended to form the final end product.

As with any other large system, refineries contain certain essential parts. Regardless of refinery category, the distillation towers are, according to Mr William Fiedler, an independent oil consultant, the "heart of the refinery."[124] Without the specially designed large, cylindrical distillation towers, the entire refining process is dramatically curtailed, if not entirely shut down. Destroying the cracking and reformation towers will further complicate the recovery process, but to attack these without destroying the distillation towers will not totally stop the production of basic gasoline.[125] The towers, in a small refinery (17,500 barrels/day), are typically 100 feet tall, range anywhere from 15 to 25 feet wide, and may be constructed with steel plating up to one and one-half inches thick. The towers may be tested up to 60 pounds per square inch (psi) internal pressure and may, in fact, be able to withstand even greater pressure from an external explosion.[126] Furthermore, the towers in larger refineries may be up to three times the size of those found in small refineries.

As for repair or replacement, it is extremely difficult and time-consuming. All of the towers are generally one-of-a-kind type of items, specifically designed and constructed for individual refining units. According to Mr James Edgerly, a project manager for Blount, Inc., the absolute minimum time required to build a new refinery would be at least a year.[127] To repair bomb damage and replace any one of the three types of towers would take at least three and one-half to four months. To replace a tower, it must first be constructed at an industrial fabrication shop specializing in coated vessels and then transported to the job site.[128] Once there, a refractory (a concrete-like internal coating designed to protect the tower from heat and catalyst reactions) must be applied internally, and then the systems must be tested. Finally, the time estimate to replace a tower is based upon minimum collateral damage. In the case of a major fire, which is a distinct possibility, to repair and replace a refining unit could easily exceed six months assuming everything goes as planned.

Further aggravating destruction is the fact that only a handful of companies throughout the world, primarily in developed countries, actually build refineries.[129] Although some local expertise may exist, many developing countries simply do not have the intellectual or technical ability to rebuild damaged refineries in short order.[130] (The fact most of the companies are from the First World tends to make the targeting problem easier, since the planners may have access to the actual refinery plans and can optimize precision targeting capabilities.)

Regardless of the level of attack (i.e., storage facilities, resupply networks, or harbors/refineries) nonlethal weapons offer a relatively new method of conveying a message or accomplishing the mission. In the case of nonlethal weaponry, it is not so much where one accomplishes the damage or destruction, but how. At present, little information is available regarding how one might go about targeting oil or refined petroleum products, but at least two alternatives seem to exist. The first involves the use of oil-soluble agents. For instance, it appears that some form of chlorine or oil-soluble oxygenating agent (i.e., mothballs) could render the catalyst in the cracking towers ineffective, thereby causing an interruption in the refining process of something close to a week.[131] Special Operating Forces (SOFs) could introduce such an agent into the raw crude supply of a refinery by tapping into the feed line or into a tanker during terminal operations. Clearly, an oil-soluble agent offers one the ability to convey a message without having to destroy anything.

The second method involves the use of microorganisms similar to those used in bioremediation.[132] The organisms are basically enzymes which feed on any organic, carbon containing molecule. The "bugs are most effective at attacking petroleum hydrocarbons, especially the short chains."[133] The "bugs" can be genetically engineered for optimum effectiveness, and "dried and stored as a powdery mixture that resembles instant pancake mix and has a shelf life of about a year. Some strains double in volume as often as once every 20 minutes."[134] Since the "bugs" can be genetically engineered, it is theoretically possible to design a "bug" to render any type of petroleum product useless. In fact, it appears as though one might be able to poison the entire petroleum-based sector of a nation. For example, consider the effects of a supertanker off-loading its entire cargo of petroleum laced with a time-activated microorganism into the Japanese petroleum system. The effects could be disastrous. Without destroying any portion of the infrastructure, the entire nation could be brought to its knees. At this time, it is difficult to assess the overall utility of such organisms, but in the future, planners may not only have to decide what and where to strike, but whether to strike with lethal or nonlethal weapons.

Summary

Oil does, and will continue to, play a vital role in conventional warfare. As the pace of conventional warfare increases, planners must seek and achieve immediate results. When considering oil, such results are best achieved by targeting tactical-level fuel storage, intermediate-level resupply networks, and strategic-level harbors and refineries. While both lethal and nonlethal means are certainly available, numerous other factors exist which warrant consideration and future study. For instance, someone might want to consider the depth of the industry. Just how much time is required for the refined product to travel from production to user? The answer is particularly important if one chooses to target refineries first. Or, in a relatively shallow industry, is it possible to shut down a refinery with nonlethal weapons and immediately affect flight and/or ground operations? Or, what about any special economies which might exist within an enemy's petroleum industry? In other words, are alternative sources of production available (i.e., obsolete equipment) prototype or training models, equipment in mothball status, or simply that which is easily salvaged or repaired? Or finally, what about the collateral effects of targeting oil? In considering collateral effects, it seems necessary to not only consider those which result from the destruction of certain portions of the petroleum system (downstream collateral effects), but those which can affect the industry as well (upstream collateral effects). For instance, what type of catalyst and additives are used in the refining process and are they readily available? Or, how about the multitude of products which are dependent upon the huge petrochemical industry immediately downstream of the refining process? Are any of the products essential to the military? The fact remains, hundreds of questions must be asked and answered regarding this and other critical industries.

Chapter 5

Conclusion

Successful warfare requires not only adequate military forces but advanced economic systems capable of supporting these forces. Such systems inherently provide large, soft, and extremely vulnerable targets that are susceptible to enemy attack, specifically enemy air attack. The key is to strike a concentrated industry which is vital to the prosecution of a war. The petroleum-based sector of a nation's economic infrastructure is generally concentrated and often a prime target set. By striking oil-related targets, it is possible to immobilize and destroy an opponent's military force. Furthermore, one can force the opponent's civilian population to share the effects of attack without being exposed to direct bombardment.

To properly understand the effects of targeting oil, this study has sought to determine the fundamental utility of targeting and attacking the petroleum-based sector of a nation's economy. The study devoted specific attention to the *why* of the petroleum target set. Ideally, the reader is now able to better understand whether petroleum is critical to a nation and, in those cases where it is, how to go about destroying it.

Historical precedents do play an important role in the success of any future targeting strategy, including oil. While a number of conflicts are available for study, World War II and Vietnam seem to offer the best historical perspectives. In the case of World War II, the Allies fought an unlimited war against the Axis powers. However, with the advent of nuclear weapons, the US fought a limited war in Vietnam in the shadow of the nuclear threat. As for targeting oil in past wars, the planners learned many valuable lessons, many of which remain applicable today. The major lessons of World War II and Vietnam are as follows:

- Strategic intelligence is a must.
- Civilian targeting experts are a must.
- Doctrine is not a synonym for targeting.
- Centers of gravity are not necessarily subject to attack.
- One must anticipate the collateral effects of bombardment.
- Air superiority may be possible as a result of POL targeting.
- Mirror imaging is a constant problem.
- One must plan to work around sanctuaries.

The fact remains, oil proved to be an extremely effective target during World War II but an illusive and frustrating target during Vietnam.

Although oil has enjoyed only limited success as a suitable target in the past, the future appears bright. First of all, oil appears to be relatively plentiful, it does not appear to be a likely candidate for replacement by an alternative energy source anytime in the near future, and consumption seems to be increasing slowly. Furthermore, while it is impossible to tell from the results of the Gulf War, oil will most likely play a major role in future wars, particularly in large-scale conventional conflicts. Finally, with the advent of hyperwar, targeting must now achieve immediate, "user first" results. Therefore, in the case of oil, one should strike tactical-level storage facilities first, followed by pipeline pumping stations, and then refineries or points of importation. In the case of refineries, the most appropriate targets appear to be distillation towers. Furthermore, it may now be possible to render a nation's entire raw crude and refined petroleum product stockpile useless with the use of nonlethal oxygenating agents or microorganisms similar to those used in bioremediation. In sum, the petroleum-based sector of a national economy, in many cases, is an appropriate target in order to affect enemy military operations.

As the United States Air Force prepares to enter the 21st century, many of the original problems encountered during previous wars are either outdated or now draw critical attention. Given current and future technological developments, it appears possible to identify, target, and destroy the critical components of an enemy's petroleum industry, thereby greatly enhancing one's chances of victory. Given the continued importance of oil, Daniel Yergin rightly states in his book, *The Prize*, "For ours is a century in which every facet of our civilization has been transformed by the modern and mesmerizing alchemy of petroleum. Ours truly remains the age of oil."[135]

Notes

1. Carl von Clausewitz, *On War,* ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 75.

2. Ibid., 77. (Emphasis in original.)

3. Peter Paret, ed., *Makers of Modern Strategy* (Princeton: Princeton University Press, 1986), 538.

4. Maj Muir S. Fairchild, "National Economic Structure," lecture, lecture no. AF-7-C, Air Corps Tactical School, Maxwell Field, Ala., 2 November 1939, 12.

5. Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany, 1939–1945,* 4 vols. (London: His Majesty's Stationery Office (HMSO), 1961), vol. 1, *Preparation,* 28.

6. Ibid., 28.

7. Ibid. Communications (lines of communications) and transportation comprise the original target system identified by Webster and Frankland in their work.

8. Ibid., 94.

9. Alan J. Levine, *The Strategic Bombing of Germany, 1940–1945* (Westport, Conn.: Praeger Publishers, 1992), 9.

10. F. H. Hinsley, *British Intelligence in the Second World War,* 5 vols. (New York: Cambridge University Press, 1979), vol. 1, 241.

11. During the first half of 1941, German U-boats and Focke-Wulf bombers severely challenged Allied seaborne trade by sinking more than 2,000,000 tons of Allied shipping. As a result, RAF bombers switched targeting emphasis to U-boats at sea, U-boat construction yards and maintenance facilities, and Focke-Wulf aircraft factories and airfields. In May 1943, bombing emphasis shifted again as the combined chiefs of staff meeting at the Trident Conference directed that the German aircraft industry and fighter forces be made the top priority due to increasing Luftwaffe strength. Finally, in early 1944, General Eisenhower directed Allied bombers to concentrate their efforts against the German transportation system, specifically the railroads and marshaling yards required for German resupply and reinforcement efforts in northwest France.

12. Wesley Frank Craven and James Lea Cate, *The Army Air Forces in World War II,* 7 vols. (Chicago: University of Chicago Press, 1948–1958), vol. 3, *Europe: Argument to V-E Day,* 172.

13. Maj Gen Haywood S. Hansell, Jr., *The Air Plan that Defeated Hitler* (Atlanta: Higgins-McArthur/Longino & Porter, Inc., 1972), 79.

14. War Department, Office of the Chief of the Army Air Forces, *AWPD/1 Munitions Requirements of the Army Air Forces,* 12 August 1941, 2.

15. Ibid., 7.

16. Memorandum, President Franklin D. Roosevelt to Gen George C. Marshall, chairman of the Joint Chiefs of Staff, 24 August 1942.

17. Oil slipped from fourth to fifth priority between the two AWPDs as a result of the German U-boat/bomber menace and the subsequent Battle of the Atlantic.

18. War Department, Office of the Chief of the Army Air Forces, *AWPD/42,* 9 September 1942, pt. 4, 3.

19. Guido R. Perera, *Leaves from My Book of Life,* vol. 2., *Washington and the War Years* (Boston: privately printed, 1975), 79. After discussing study results with officers of the Eighth Air Force, the Economic Warfare Division of the American embassy in London, and the MEW, COA members Fowler Hamilton, Bart Leach, and Guido Perera decided it was best to not openly rate the target systems by priority so as to give the operating authorities in England the greatest possible latitude.

20. Ibid., 95.

21. Craven and Cate, vol. 2, *Europe: Torch to Pointblank,* 357.

22. Perera, 72.

23. Ibid., 95.

24. Committee of Operational Analysts, Electrical Equipment, Oil and Chemicals Subcommittee, *Western Axis Oil Industry,* 16 January 1943, sect. 3, 4–6.

25. Webster and Frankland, vol. 2, *Endeavour,* 15.

26. Quoted in Webster and Frankland, vol. 4, *Annexes and Appendices,* 273. Quote is extracted from "The Combined Bomber Offensive from the United Kingdom (Pointblank)," approved by the combined chiefs of staff on 14 May 1943 as published in the book.

27. Ibid., 274. Probably the most important lesson of the CBO was "the failure to concentrate at an earlier date on oil and to appreciate the vital interdependence of synthetic oil, synthetic rubber, nitrogen, and other elements in the vast chemical complex." (Craven and Cate, vol. 2, 367.) If the Allied air forces had actually concentrated their limited assets on oil stocks and associated refining facilities early in the war, the entire German war machine might have collapsed sooner.

For instance, ethyl fluid, a product of the tetraethyl lead plants, was an indispendable element of high-grade aviation gasoline. By destroying any of the *three* critical plants producing it, the resulting Allied advantage might have led to earlier air superiority and subsequent war termination.

28. The plan General Spaatz presented was actually the result of a cooperative agreement and understanding between the EOU and General Spaatz. The basis for the plan was the EOU report entitled "The Use of Strategic Air Power after 1 March 1944" which studied historical directives, current target systems, and explored the merits of oil targeting and various alternatives.

29. Craven and Cate, vol. 3, 173.

30. Ibid., 174.

31. The British "Transportation Plan" simply sought to interdict road and rail traffic essential to the German defense of northwest France.

32. Interestingly enough, General Spaatz actually threatened resignation before General Eisenhower granted permission. Dr David R. Mets, interview with author, School of Advanced Airpower Studies, Maxwell AFB, Ala., 15 February 1993.

33. Craven and Cate, vol. 3, 177.

34. Albert Speer, *Inside the Third Reich*, trans. by Richard and Clara Winston (New York: Macmillian Co., 1970), 346.

35. Questions are derivations of those posed by Webster and Frankland, vol. 1, 28; Hansell, 79; and Perera, 95.

36. United States Strategic Bombing Survey (USSBS), Oil Division, *The German Oil Industry Ministerial Report Team* 78, January 1947, 4.

37. Ibid., 76.

38. Certain members of the ACTS had actually requested industrial intelligence from the Army Industrial College, but their request was denied as war mobilization had become the number one priority of the college.

39. USSBS Oil Division, *Ministerial Report Team* 78, 52.

40. USSBS Oil Division, *Oil Division Final Report European Theater*, January 1947, 10.

41. USSBS Oil Division, *Ministerial Report Team* 78, 62.

42. Stanford Research Institute, *Impact of Air Attack in World War II: Selected Data for Civil Defense Planning*, SRI Project 669, Division 2 (Stanford, Calif.: SRI, June 1953), vol. 1, pt. 1, 58.

43. USSBS Oil Division, *Final Report*, 2.

44. Ibid., 123.

45. Bernard Brodie, *War & Politics* (New York: Macmillian Publishing Co., 1973), 106.

46. Mark Clodfelter, *The Limits of Airpower* (New York: Free Press, 1989), 74.

47. Ibid., 75.

48. Wesley R. C. Melyan and Lee Bonetti, "ROLLING THUNDER July 1965–December 1966," Project CHECO Report, 15 July 1967, 24.

49. Col Dennis M. Drew, "Rolling Thunder 1965: Anatomy of a Failure" (CADRE Paper, Maxwell AFB, Ala.: Air University, 1986), 29.

50. Clodfelter, 85.

51. Ibid., 88.

52. According to *The Pentagon Papers: The Defense Department History of United States Decisionmaking in Vietnam*, 5 vols. Senator Gravel edition (Boston: Beacon Press, 1971), vol. 4, 59, "of the remaining 114 targets, two-thirds (75) were in the off-limit areas, and 29 of the other remaining 39 were in the touchy northeast quadrant."

53. Clodfelter, 90.

54. *The Pentagon Papers*, vol. 4, 60.

55. Ibid.

56. Ibid., 109.

57. Ibid.

58. Ibid., lll–120.

59. *The Pentagon Papers*, vol. 3, 111.

60. Adm U. S. G. Sharp, USN, "Report on the War in Vietnam (as of 30 June 1968)," 30.

61. *The Pentagon Papers*, vol. 4, 111. The report was one of the JASON Summer Study reports.

62. Ibid., 109.

63. William Morris, ed., *The American Heritage Dictionary of the English Language* (New York: American Heritage Publishing Co., Inc., 1971), 1148.

64. Brodie, 66.

65. Department of Energy, Energy Information Agency, *International Energy Annual 1991* (Washington, D.C.: Government Printing Office (GPO), December 1992), 99.

66. Ibid., 21. The four countries and respective consumption rates are: United States (25.1), former USSR (12.3), Japan (7.9), and Germany (4.2).

67. Dr Charles D. Haynes, professor of Mineral Engineering, University of Alabama, Tuscaloosa, Ala., interview with author, 24 February 1993.

68. World Resources Institute, *World Resources 1992–1993* (New York: Oxford University Press, 1992), 144.

69. Ibid., 143.

70. *International Petroleum Encyclopedia* (Tulsa, Okla.: PennWell Publishing Co., 1990), 6. The data is further collaborated in the *International Energy Annual 1991*. The DOE book confirms the following growth rates: North America - 1.0; Western Europe - 0.7; Far East and Oceania - 3.6; Middle East - 4.6; Central and South America - 0.9; and Africa - 3.0.

71. Eric Goodger and Ray Vere, *Aviation Fuels Technology* (Hong Kong: Macmillian Publishers Ltd., 1985), 228. According to this source, avgas is becoming a specialty product produced through an expensive batch processing. Its high price is maintained by the dedicated processing and distribution system. Approximately 50 percent of general aviation is served by avgas.

72. Ibid., 229.

73. Col John A. Warden III, "Employing Air Power in the Twenty-first Century," in *The Future of Air Power in the Aftermath of the Gulf War*, ed. Richard H. Shultz, Jr., and Robert L. Pfaltzgraff, Jr. (Maxwell AFB, Ala.: Air University Press, July 1992), 79. Near-simultaneous attack is also referred to as parallel attack.

74. Maj Jason B. Barlow, "Strategic Paralysis: An Airpower Theory for the Present" (master's thesis, School of Advanced Airpower Studies (SAAS), Air University, Maxwell AFB, Ala., May 1992), 3.

75. The air campaign consisted of three phases—a strategic phase designed to paralyze all facets of the Iraqi infrastructure, a Kuwaiti theater of operations (KTO) phase designed to suppress enemy air defenses in the KTO, and a final phase to eliminate the Republican Guard and other elements of the Iraqi army in Kuwait and Iraq.

76. Col John A. Warden III, interview with author, Maxwell AFB, Ala., 7 December 1992.

77. Department of Defense, *Gulf War Air Power Survey, Summary Volume* (Washington, D.C.: Office of the Secretary of Defense, 1993), chap. 3, 9.

78. The idea of "organic essentials" originates with Col John A. Warden III, USAF. Within his theory of air power application, he postulates the need to attack "five rings." They are leadership, organic essentials, infrastructure, population, and fielded military forces. Organic essentials consist of electrical power and petroleum refining capability.

79. Col John A. Warden III, "The Enemy as a System" (unpublished paper, Air University, Maxwell AFB, Ala., 3 January 1993), 16.

80. Secretary of Defense (SECDEF) Report, *Conduct of the Persian Gulf War*(U), 4-2.

81. Department of the Air Force, *Reaching Globally, Reaching Powerfully: The United States Air Force in the Gulf War* (Washington, D.C.: GPO, September 1991), 31.

82. "Kuwait's Oil Industry Slowly Recovering," *Oil & Gas Journal*, 2 September 1992, 36. The article states that the giant Mina al-Ahmadi refinery is only just beginning to return to normal more than seven months after the Coalition victory. The Kuwaiti Petroleum Corporation states that the refinery should be producing approximately 170,000 barrels per day (b/d) by the end of September, but notes that production will most likely not exceed 170,000 b/d in the short term. Prewar production capability was 370,000 b/d. In considering the amount of time required to return the facility to some state of productive capability, one must note the availability and assistance of international agencies and corporations as compared to a nation still under international sanctions (i.e., Iraq).

83. USAF Report, *Reaching Globally, Reaching Powerfully*, 31.

84. Dr Sandy Cochran, "Gulf War Air Power Survey" at briefing, Air University, Maxwell AFB, Ala., 5 February 1993.

85. Colonel Warden interview, 7 December 1992.

86. Ibid.

87. USAF Report, *Reaching Globally, Reaching Powerfully*, 31.

88. The "user first" model is a model developed by the author in response to the need to achieve immediate results given the advent of hyperwar. It seeks to eliminate critical supplies, in this case POL, required by the enemy military forces to engage in warfare.

89. Elasticity of supply is basically defined as the ability of an entity to continue near normal opeations through the use of existing stocks on hand when the flow of resupply is halted.

90. Dual-use targets are those targets which not only affect military operations or those essential to military operations, but civilian populations as well. It is not until this stage of the war that this method of targeting considers the idea of collective responsibility professed by Colonel Warden.

91. While it is conceivable to eliminate all crude input to a refinery, it is also worth noting that any damage done is easily repaired and supply restored.

92. Department of the Navy, Bureau of Naval Personnel, *Fundamentals of Petroleum* (Washington, D.C.: GPO, 1953), 113–125.

93. Capt Louis Nicholas, "Petroleum, Oil, Lubricants (POL) Systems on US Overseas Air Bases" (Kirtland AFB, N. Mex.: Air Force Weapons Laboratory, November 1988), 21–22. Storage, particularly overseas, consists primarily of underground storage, partially buried and bermed "cut-and-cover" double-walled steel tanks, and above ground urethane bladders. "Cut-and-cover" tanks hold anywhere from 300,000 to 1,300,000 gallons of fuel while the bladders range up to 50,000 gallons. One should also note that most fuel tanks at civilian airports and military bases in the United States are above ground due to low terrorist threat, cost, and the need for cathodic protection (prevention of corrosion from minor electrical currents).

94. Ibid., 11–20. In that pipelines are the most common and effective form of delivery, one must logically be concerned with immediate resupply capability. Pipelines usually deliver fuel at a rate of 300 to 500 gal/min, but do not do so continuously as the typical base only receives periodic fuel shipments. As a side, "current truck/train offload systems can only be used as a supplement to the pipeline or barge offload system." They cannot meet the demands of an average ACC air base wing.

95. Ibid., 13–19, and Technical Sergeants David C. Young and Joseph C. Hanel, USAF POL specialists, interview with author, Maxwell AFB, Ala., 30 April 1993.

96. Ibid., 47. At present, the Liquid Fuels Maintenance section of base level Civil Engineering has portable pumps designed to remove trapped fuel from storage tanks. The section, however, is not equipped to repair serious damage to the base level POL infrastructure.

97. According to Sergeants Young and Hanel, while 50,000 gallon neoprene bladders are supposedly available, neither of the two overseas bases at which they were stationed (one each PACAF and USAFE) had a bladder readily available.

98. Captain Nicholas, 27. An additional factor worthy of consideration is the flash point and vapor pressure of the fuel. In the case of JP-8, the flash point/vapor pressure is 100 degrees F/near zero versus –20 degrees F/2 to 3 pounds per square inch absolute (psia) for JP-4. In other words, JP-8 is much more stable than JP-4 unless exposed to air and higher temperatures. Basic gasoline is much more unstable with a flash point of –50 degrees F and a vapor pressure of 7 to 14 psia.

99. Ibid., 28.

100. Noel Griese, public affairs manager, and Dode Edmonds, manager of Operations Planning and Pipeline Control, Colonial Pipeline Company, telephone interview with author, 28 April 1993. Apparently fuel destined for Atlanta International Airport flows into holding tanks before moving onto the airport proper. The tanks are located 10 to 15 miles from the airport.

101. Warren R. True, "1990 US Interstate Pipelines' Efficiency Continues Improving," *Oil & Gas Journal*, 25 November 1991, 42.

102. Colonial Pipeline Company, Information Handbook, revised October 1992, 15.

103. Ibid., 12.

104. According to Noel Griese of the Colonial Pipeline Company, Colonial maintains four emergency response teams for just such an emergency. Furthermore, the Air Force recently demonstrated the ability to "make expedient repairs on bomb-damaged POL distribution piping to temporarily restore the base POL distribution system." USAF Air Warfare Center, *Petroleum, Oil, and Lubricant (POL) Distribution System Rapid Utility Repair Kit (RURK) - Phase I IOT&E Final Report* (Eglin AFB, Fla.: Air Combat Command, July 1992), i.

105. According to a 1979 General Accounting Office report entitled *Key Crude Oil and Products Pipelines Are Vulnerable to Disruptions*, no suitable transportation alternatives exist for the Colonial pipeline. The pipeline volume of 75,000,000 gal/day is simply too great. According to Mr Griese and Mr Edmonds of the Colonial Pipeline Company, it would take more than 88,000 tank trucks to move the same amount of fuel.

106. Maynard M. Stephens, *Vulnerability of Total Petroleum Systems*, Defense Civil Preparedness Agency report (Washington, D.C.: DCPA, May 1973), 34.

107. General Accounting Office, *Key Crude Oil and Products Pipelines Are Vulnerable to Distruptions* (Washington, D.C.: General Accounting Office, 27 August 1979), vi.

108. Congressional Research Service, *National Energy Transportation, vol. III - Issues and Problems*, Publication No. 95–15 (Washington, D.C.: GPO, March 1978), 165. The report goes on to say that while the pipeline was not damaged, it was shut down for 10 days as a safety precaution. Furthermore, William Fiedler, a former defense fuel region commander for Alaska, highlights the fact that as oil cools in a pipeline it becomes more difficult to move (difficulty of movement is a function of viscosity and temperature).

109. Richard L. Goen, Richard B. Bothun, and Frank E. Walker, *Potential Vulnerabilities Affecting National Survival* (Stanford, Calif.: Stanford Research Institute, September 1970), 162.

110. GAO Report, 27 August 1979, 22.

111. Noel Griese and Dode Edmonds, Colonial Pipeline Co., telephone interview with author, 28 April 1993.

112. Ibid. According to Mr Edmonds and Mr Griese, the loss of a single station will result in a 20-percent reduction in flow rate, and the loss of a second station will result in the loss of an additional 20 percent and flow termination. The reason for shutdown is certain Department of Transportation (DOT) regulations which preclude the continued operation of a pipeline above 72 percent of its rated yield strength. Both men stated that continued pipeline operation was possible if the government was willing to waive the restrictions.

113. Mr Griese, Mr Edmonds, and the author all speculated that since the pumps produce heat in excess of 100+ degrees F, it would be fairly easy to identify them against the somewhat cooler pipeline. Also, planners should be aware of the fact that some booster stations overseas, particularly in those nations prone to war, may be camouflaged in buildings or underground.

114. Otto Doner, BWIP Pump Division, telephone interview with author, 28 April 1993. After explaining to Mr Doner the damage to the booster station would be similar to that done by USAF aircraft to stop the oil spill into the Persian Gulf during the Gulf War, he concluded an entire booster station would have to be rebuilt. To do so, the critical link is the time to manufacture the pumps themselves. The average time from order to completion is 29 weeks, but he feels 16 weeks might be possible with another four weeks to install. If for some reason the pumps were only damaged at a booster station, the time to remachine and reinstall might be closer to eight weeks.

115. Ibid.

116. As for Colonial moving pumps, no one wanted to guess how long it might take. Mr Doner of BWIP noted that a new "base plate" would have to be constructed and suitable foundations poured. A very rough guess is something close to eight weeks. Furthermore, few pipelines worldwide have the resources to allow them to run with in-line spares in which case the option is simply not available.

117. "Iraqi oil industry slowly returning to normal," *Oil & Gas Journal*, 7 September 1992, 22–23. The terminal consists of two pumping stations, a 45km stretch of pipeline to the terminal, and one each 36- and 48-inch-diameter pillars which feed the loading piers. The facility was previously destroyed in the Iran-Iraq war and rebuilt in 18 months at a cost of $140 million. One might also note the fact that the terminal, once construction began, was built in approximately one-half the time it took to rebuild the terminal the first time. While a number of reasons may exist, one should not discount the possibility of lessons learned and design changes made as a result of the first strike.

118. In targeting marine terminals, one should be aware of the specific timing. In other words, since oil tankers run on very predictable schedules, the actual timing of an attack can further compound the situation in the field. Consider the effect of a covert attack against a critically important marine facility, or how about the destruction of a tanker in a channel at either the end of the Japanese supply line during World War II.

119. Fereidun Fesharaki and David T. Isaak, *OPEC, the Gulf, and the World Petroleum Market* (Boulder, Colo.: Westview Press, Inc., 1983), 71.

120. According to Professor Haynes and Associate Professors Phillip W. Johnson and Peter E. Clark of the University of Alabama at Tuscaloosa, a petroleum engineer should be able to tell exactly what type of crude a refinery processes and what it is capable of producing.

121. Organization of the Petroleum Exporting Countries (OPEC), *Basic Oil Industry Information* (Vienna, Austria: Public Information Department of OPEC, 1983), 30.

122. Five generic cracking processes are generally used according to Fesharaki and Issak. They are catalytic cracking, distillate hydrocracking, coking, visbreaking, and residuum hydrocracking. Catalytic cracking and distillate hydrocracking are generally used to manufacture gasolines and medium distillates (kerosene, gas oils, and diesel fuels). "Few refineries are equipped with more than one type of cracking technology."

123. OPEC, *Basic Oil Information Handbook,* 31.

124. William Fiedler, independent oil consultant, telephone interview with author, 14 April 1993. According to one CIA analyst, steam plants may also serve as a suitable target. The logic is that steam plants supply the essential heat and electricity for refinery operation. One must realize, however, that while steam is important, commercially "packaged boilers" can, in fact, be used in place of a steam plant. "Packaged boilers" are generally self-contained and can be on-site and in operation within one week. Furthermore, one should also realize that commercial electricity may be available.

125. Certain refined petroleum products are available after simple distillation; however, catalytic crackers appear to be essential to the production of high-grade aviation gasoline.

126. James Edgerly, project manager, Blount, Inc., interview with author, Montgomery, Ala., 27 April 1993.

127. Blount, Inc., is an American construction firm who builds refineries, among other things.

128. It is not uncommon for old refining units (towers) to be used when building a new unit. However, old towers must be located, transported, erected, have the refractory applied, and then tested. The time involved is not significantly different from that of a new tower. Furthermore, towers are specifically designed to be used in concert with the other elements of the refining unit and cannot generally be inserted where one desires.

129. The following American companies are just a few of the world's largest engineering and construction firms involved with refineries: Becthel, Fluor-Daniel, Brown and Root, Catalytic, and Foster-Wheeler.

130. Simply consider the difference in time required to rebuild existing oil infrastructures in Iraq versus Kuwait.

131. Professor Haynes and Associate Professors Johnson and Clark, interview with author, 24 February 1993. Further compounding the problem is the actual availability of catalyst compound. If it were possible to deny platinum, or another popular and commonly used catalyst, it might be possible to shut down a refinery for an indefinite amount of time without destroying any part of it.

132. Bioremedation can be defined as using living microorganisms to clean up waste.

133. Reed Ableson, "Bugs Clean Up Their Act," *Forbes*, 28 September 1992, 144.

134. Ann M. Thayer, "Bioremediation: Innovative Technology for Cleaning Up Hazardous Waste," *Chemical and Engineering News*, 26 August 1991, 44; and Richard A. Marini, "Bacteria versus Oil Spills," *Popular Science,* July 1992, 74.

135. Daniel Yergin, *The Prize* (New York: Simon & Schuster, 1991), 781.

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